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LTL-M MOBILE RETROREFLECTOMETER

User Manual

Mobile quality control of road markings in accordance with CEN / ASTM specifications

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SECTION 1

OPERATING INFORMATION

LTL-M introduction

The LTL-M retroreflectometer is a mobile field instrument intended for measuring the retroreflection properties of road/pavement markings. LTL-M measures the R_L value (coefficient of retroreflected luminance) and the DC (Daylight Contrast) as well as records the presence of RPMs (Raised Pavement Markers also called road studs). R_L is a measurement of the lightness of the pavement marking as seen by drivers of motorized vehicles in car headlight illumination at nighttime. The daylight contrast is the contrast between the road surface and the marking seen by the driver at daytime. RPMs are another means of guiding traffic at nighttime through small devices positioned on the road surface providing a strong retroreflection.

LTL-M measures at traffic speed. LTL-M will provide 100% coverage of the markings at 90 kph / 55 mph but can measure at lower and higher driving speed. At speed > 90 kph / 55 mph the coverage will be less than 100%, the rate depending on the actual speed.

LTL-M defines a marking as an area of the road surface providing a retroreflection of minimum 40 mcd/lx/m^2. A marking will be recognized as such if it is minimum 1 m / 3 feet long and minimum 5 cm / 2 inch wide. Double lines will be recognized if there is minimum 5 cm / 2 inch between the two lines. LTL-M can measures markings up to minimum 50 cm / 20 inch wide.

EN 1436 standard (EU)

The road is illuminated at an angle of 1.24° and the reflected light is measured at an angle of 2.29°, which corresponds to an observation distance of 30 m / 98 feet.

ASTM E 1710 standard (USA)

The road is illuminated at an angle of 88.76° and the reflected light is measured at an angle of 1.05°, which corresponds to an observation distance of 30 m / 98 feet.

This is relevant for a motorist's viewing situation under normal driving conditions. The LTL-M system based on 30 m geometry compressed to 6 m / 19.7 feet measuring distance.

Further information on measuring principles and standards can be found on www.roadsensors.com under Technology.

The operation of the retroreflectometer is simple and requires minimal instruction, see SECTION 3 for details.

RL is an important factor in the **ON-SITE** quality control of pavement markings.

The LTL-M sensor mounted on a vehicle

Measuring R_L and DC

The LTL-M system measures the retroreflectivity and calculates R_L according to the international CEN and ASTM standards in mcd/lux/m^2. LTL-M measures in addition the daylight contrast which is a relative measurement giving the contrast ratio between the road surface and the marking. Measurement results are presented as figures (R_L and DC), columns (R_L) and graphs (R_L) directly on the system TabletPC or after transfer of data on a PC. Error messages or warnings are shown in the display in case of any problems during use as pop-up.

RPM's

The LTL-M system records automatically the presence of RPM's. RPM's with a retroreflection of minimum 2% of the level of new RPMs as stated in EN 1463 will be recognized. The data can be located in the log.

Data capture

The LTL-M system stores R_L, DC and RPM data with corresponding date, time, GPS coordinates and other relevant data. The following data is also registered:

- Name and other information on the road (Series ID)
- User name (Users ID)
- Distance to measure and to go
- Width of marking
- Driving speed
- Comments entered during driving
- Quality of GPS fix

LTL-M provides during driving on the system tabletPC graphical information about the RL measurement results as well as a visual view from the measurement camera allowing the driver to navigate the vehicle.

LTL-M retroreflectometer features

- Mobile instrument for mounting on a vehicle
- Measuring R_L on dry and wet marking surfaces
- Measures flat, textured & profiled markings
- Calculate daylight contrast
- Records presence of working RPMs
- Fully documented measurements with automatic data storage, user and series identification for labeling and grouping of measurements
- Audible signals during use (if enabled)
- Easy calibration procedure
- Traceable and accredited calibrated reflection standard
- Results in histogram graph
- Average result presentation from 1 m to indefinite

Options

- Overhead camera
- DMI (Distance Measurement Instrument)

Getting started

The LTL-M base system consists of three parts

The Sensor

The Processor

The TabletPC

The Sensor

The sensor measures the R_L value of the markings, the daylight contrast (DC) and the presence of RPMs. The sensor is mounted on the left or the right side of the vehicle. The sensor is being connected to the processor by two proprietary cables for power supply and data transfer. The sensor is being turned on and off through the Processor.

Before starting measurements the sensor need to be calibrated, see the section on Run **Calibration** on page 20-21.

The Processor

The processor is the unit storing and processing measurements and recorded data. The processor is placed in a safe place inside the vehicle preferably locked to ensure that it does not move during driving. The processor is connected to the car's 12 v battery for power and to the sensor using two proprietary cables for power supply and data transfer. The Processor together with the Sensor is turned on and off on the green button at the back of the Processor box.

Data is stored on an internal hard disc. The set-up of the hard disk is unique to a specific instrument. If you want a back-up hard disk you need to mirror the existing hard disk. A mirrored hard disk may be ordered at DELTA at the time of purchase.

The TabletPC

The TabletPC is the main tool for the user to operate the LTL-M system and follow the results of the measurements. The Tablet PC has a number of functions described below. Remember that the TabletPC screen responds to your fingers ability to transfer electricity and not to pressure and that it make take a little while for the screen to respond.

The TablePC Main Page

Mounting and switch on

The TabletPC is placed next to the driver in the holder provided with the system for easy mounting. Before turning on the TabletPC turn on the Processor.

The TabletPC is turned on on the button at the upper right corner of the unit. Once the unit has powered up unlock the display by sliding the “key symbol” upwards to operate the screen.

Unlock button

Click on the DELTA icon to open the software.

DELTA Icon

The following icons page access can be located on the upper part of the TabletPC screen:

Main page 

The main page is where the LTL-M system is being operated from and where the user can observe the measurement results and other parameters related to the measurement. The main page also allows the user to adjust the sensor and add marks to the log. Before the user can start measuring he or she needs to enter information on the road (Series ID) to be measured and the user (Users ID). See the section on **Main Page** on page 16-17 for details.

Series ID 

Before measurement can be initiated a Road ID need to be entered. Information on the road like name, direction, side and length may to be entered for further road identification. See the section on **Series Page** on page 18 for details.

Users ID 

Before measurement can start information on the user need to be entered. See the section on **Users Page** on page 18 for details.

View log 

In **View log** the R_L measurement results are being presented as a graph together with figures for maximum, minimum and average readings as well as standard deviation. The user can change the average length displayed to his or her desire. This is also the page where log data and videos are exported. See the section on **View Log Page** on page 19 - 20 for details.

Tools 

The **Tools** page is used to run calibration, run system alignment, synchronize the flash when changing the lamp and calibrate the DMI unit. The page also contains various information related to diagnostics. See the section on **Tools Page** on page 20 - 22 for details.

Settings 

The **Settings** page is used for choosing the measurement units, choose measurement of the full markings or the center value only, adjust the brightness of the preview field and to enable, disable and adjust the overhead camera and DMI. The page also offers the option to define the text for the eight mark log buttons. See the section on **Settings Page** on page 22-24 for details.

Mark log option
The **Mark log** offers the option of user defining up to eight markings being logged together with the measurements. The use of the **Mark log** is to note situations related to the markings where special conditions exist e.g. dirt on the markings, water on the marking etc. One mark may be logged at any time. See the section on **Mark log** on page 22 for details.

Measurement camera view
The **Measurement camera** view shows during driving where the markings are situated compared to the width of the LTL-M measurement field. The left marking is marked in green and the right marking in red. This information will guide the driver to position the vehicle correctly on the road. See the section on the **measurement camera picture** on page 16 for details.

Measurement data presentation
Measurement data on R_L values are presented in the central part of the screen as graphs and coloums and in the lower right corner as figures. The value on the x-axis are number of measurements recorded each of 1 m length.

GPS Status
The **GPS Status** field shows the quality of the GPS fix in different colors, the number of satellite contacts and the vehicle speed. See the section on **GPS Status and speed** on page 16 for details.

Measure Distance
The **Measure Distance** field shows the actual measurement distance of the measurement camera. The distance should be as close as possible to 6 m. If the measurement distance is not correct the camera may be manually adjusted by the tablet PC arrows ↑ ↓.

Measurement
The **Measurement** field shows various details related to the measurement:

- The User ID
- The Series ID
- The total length of the marking to be measured (if entered)
- The remaining length of the marking to be measured
- The time the logging has been activated

The **Measurement** button is where the camera flash system is started and stopped and where logging of the measurement data is started and stopped. See the section on **Measurements** on page 17 for details.

Important guidelines for the correct use of the LTL-M

Positioning of the instrument on the vehicle
The LTL-M sensor needs to be mounted 10 cm above the road surface when in operation. The height is important to secure that the LTL-M system is operating according to the prescribed 30 m geometry.

Cleaning of sensor windows
Before calibration or measuring it is recommended to clean the windows in the sensor unit. The cleanliness of the windows should be checked at regular intervals during driving to secure free flow of light. Be especially aware when measuring on wet surfaces (splashing of water), dirty roads (dust or mud) or when many insects are in the air.

Mounting of the sunshade in front of the sensor reduces the risk of splashes and dirt on the windows by creating over pressure during driving.

Calibration
When mounted the LTL-M system needs to be calibrated before measurements are initiated using the supplied calibration box to ensure correct measurements. It is recommended to calibrate at least once a day or when the LTL-M sensor is being re-mounted. See the calibration section on page 20 - 21 for details.

Taking measurements
Measurements are taken at vehicle driving speed. At speed up to 90 kph / 55 mph LTL-M will measure 100% of the markings. At higher speed the measurement coverage will be less than 100% depending on the speed.

LTL-M measures an area of 1 x 1 meter / 3 x 3 feet. During driving make sure the markings are within the measurement camera field, the exact position of the markings during driving can be followed on the TabletPC.

Turning on the LTL-M system

LTL-M can be run by the vehicle 12V battery preferably connected directly to the vehicle battery at the terminals. **Do only turn on the LTL-M system / processor after the vehicle engine has been turned on as the turning on of the vehicle may remove the power supply shortly during ignition.** In such case the LTL-M processor may be corrupted and need DELTA to reinstall the software. The LTL-M system require approx. 13.5 A to operate.

To safeguard the battery supply it is recommended to have an extra battery installed in the vehicle. The LTL-M system will draw the power from the extra battery which again is connected directly to the vehicle generator

Remember:

- LTL-M is an optical precision instrument, handle with care.
- Keep the protection window and calibration unit clean.
- Store in a clean and dry environment when not in use.

Remember:

- To turn on the Processor only after the vehicle engine has been started if an extra battery has not be installed.

SECTION 2

GENERAL INFORMATION

The measurement

The LTL-M retroreflectometer is a mobile field instrument intended for measurement of the retroreflection properties of road/pavement markings. LTL-M measures the R_L value (coefficient of retroreflected luminance) and the DC (Daylight Contrast) as well as record the presence of RPMs (Raised Pavement Markers also called road studs or cat eyes). R_L is a measurement of the lightness of the pavement marking as seen by drivers of motorized vehicles in car headlight illumination at nighttime. The daylight contrast is the contrast between the road surface and the marking seen by the driver at daytime. RPMs are another means of guiding traffic at nighttime through small devices positioned on the road surface providing a strong retroreflection.

EN 1436 standard (EU)

The road is illuminated at an angle of 1.24° and the reflected light is measured at an angle of 2.29°, which corresponds to an observation distance of 30 meters / 98 feet.

ASTM E 1710 standard (USA)

The road is illuminated at an angle of 88.76° and the reflected light is measured at an angle of 1.05°, which corresponds to an observation distance of 30 meters / 98 feet.

This is relevant for a motorist's viewing situation under normal driving conditions. The LTL-M system based on a 30 meter geometry compressed to 6 m / 19.7 feet measuring distance.

Optical principle

LTL-M is based on a new patent-pending technology. The LTL-M measurement system makes use of high speed pulsating light, digital camera technology and digital image processing. A main advantage of LTL-M is the ability to deliver accurate measurement results by automatic compensation of movements in the vehicle using a digital geometry correction system. When correctly mounted, calibrated and operated the LTL-M measures with a repeatability of +/-3% and a reproducibility of +/- 5% under all driving conditions.

Based on a camera system LTL-M is measuring 100% of the markings offering "true visibility", i.e. measures retroreflection precisely as a driver in a vehicle as defined in the standards would view the markings.

V_λ spectral correction is achieved by use of advanced optical filters.

Notes on error sources

If excessive light like direct sunlight is entering the measurement system the camera measurements will automatically be discarded and no measurement will be logged. If measurements are logged they are correctly recorded.

If the markings are badly worn and no longer have the typical geometrical shape of markings, measurements will be discarded. If R_L measurements are low, approx. 40 mcd/lx/m^2 or lower, they will typically be discarded.

It is very important to keep the window and the ceramics on the calibration unit clean.

The LTL-M illumination angle is 1.24° relative to the road surface. Because of this small angle accurate placement of the instrument on the vehicle is important.

The LTL-M retroreflectometer is a rugged instrument, but it is an optical instrument and must be handled as such.

The LTL-M is factory calibrated. Nevertheless start measurements with a calibration. Study the display for any warning.

Note:

Keep the window of the instrument and ceramics on the calibration unit clean.

Environmental conditions.

The LTL-M sensor can be operated under the following environmental conditions:

Temperature	Operating	0^o - $+45^o$ C / 32^o – 113^o F
	Storage	-15^o - $+55^o$ C / 5^o – 131^o F
Humidity		Non condensing

SECTION 3

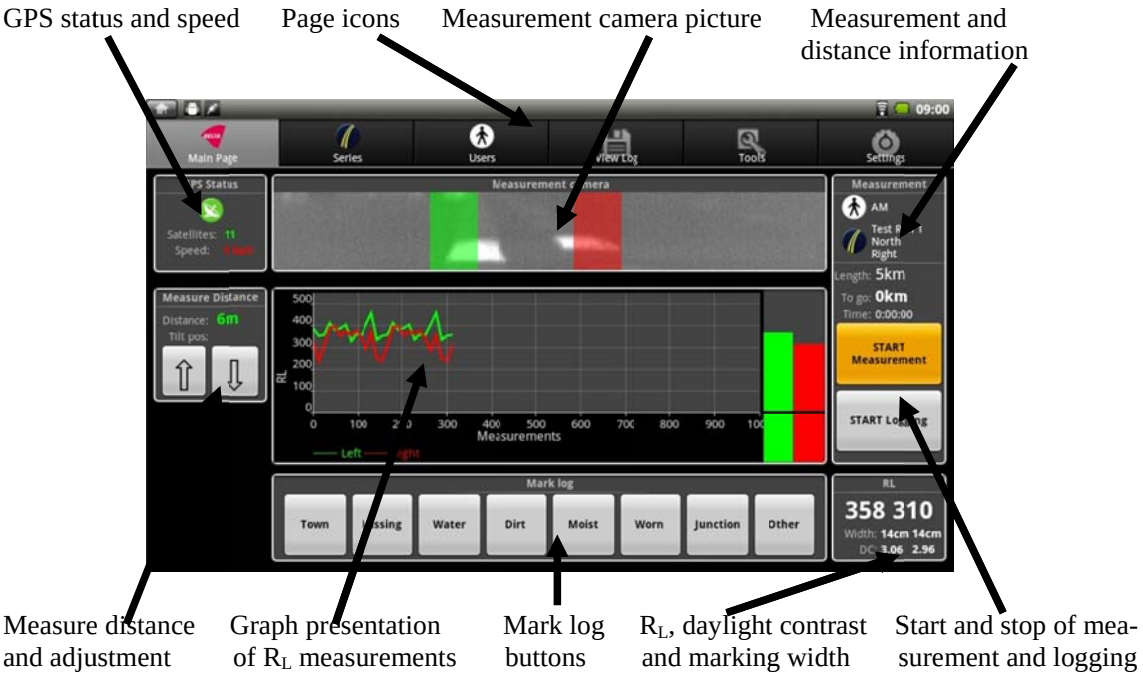
THE USER INTERFACE

INTRODUCTION

LTL-M system is controlled via the GUI (Graphical User Interface). The GUI is an Android based tabletPC to be mounted next to the driver. The GUI performs the following functions:

- Instrument configuration and control
- Measurement configuration and control
- Log viewing
- Log readout to USB drive / hard disk

The main page of the GUI can be viewed below.



MAIN PAGE

GPS status and speed

The GPS status field informs about the quality of the GPS signal and the speed of the vehicle calculated by the GPS. The color of the icon shows the quality of the position.

GOOD fix:  The GPS HDOP (Horizontal Dilution Of Precision) value is below 5.

FAIR fix:  The GPS HDOP value is larger than 5, but the GPS can FIX.

NO fix:  The GPS cannot FIX (weak or no signal).

The actual number of satellites connected is shown.

The speed can be displayed in kph (kilometer per hour) or mph (miles per hour). Adjustments of the speed unit can be made on the **Settings Page**

Page icons
Each of the six **Pages** can be accessed by a click on the corresponding icon

Measurement camera picture
The **Measurement camera** window shows a picture of the actual measurement field. The window guides the driver to position the vehicle correctly on the road – the markings has to be visible at any time for correct measuring. A green field shows the position of the left marking and a red field shows the position of the right marking if double lines are being measured. If only one marking is present it is considered a left marking and marked green.

Measurement and distance information
The **Measurement** field shows the information entered on the driver (identification of the driver) and information entered on the Series ID (identification of the road measured). In the **Measurement** field is in addition displayed the length of the road to be measured (if entered), how much of this stretch has been measured and how much time has elapsed since the measurement system has been started.

Measure distance and adjustment
The **Measure Distance** shows the distance to where the measurement system has located a marking. The geometry of the LTL-M system is based on 6 m /19.7 feet geometry therefore focus should be closest possible to this distance. Adjust instrument tilt as necessary to obtain this value. Optimal focus would be a measurement distance between 5.5 and 6.5 meters / 18 – 21 feet. On uneven roads the measurement distance may fluctuate between 5 and 7 meters / 16 – 23 feet, which are acceptable.

Adjustment of the camera is done with the two **Tilt pos.** buttons ↑ ↓.

Graph presentation of R_L measurement
The **Graph** presents the actual R_L measurement level for the left (green) and right (red) marking. If only one marking is measured it is marked green. The graph shows the actual measured R_L value over time. Making 25 measurements per second the graph shows the R_L values of the last 1.000 measurements or 40 seconds of measurements.

Mark log buttons
The **Mark log** allows the driver to enter eight custom defined marks into the log. Pushing the button briefly the mark will be logged until the button is pushed a second time. Pushing the button and holding it the mark will be logged until the button is released. One **Mark log** button can be activated at a time.

RL, daylight contrast and marking width data
This box provides the RL value, the daylight contrast (DC) value and the width of the marking as an average over the last half of a second.

Start and stop of measurement and logging
The two buttons allow the driver to start and stop the sensor (START / STOP Measurement) and start and stop logging measurement data (START / STOP Logging).

SERIES PAGE

The **Series** page is where information on the road measured can be entered. The field allows entering information on: Name, Direction, Side and Length. It is also possible to enter information on reference if applicable and comments in general. All the entered information will be stored in the log and information on road Name, Direction, Side and Length will be shown on the Main Page. New series are easily added, deleted or saved using the buttons to the right.

All fields except Length is alphanumeric and there is no min. or max. length of the data entered. Entered information may be changed after the measurements have been recorded.

If a Series is deleted a warning will be displayed that all measurements results belonging to this Series will be deleted.

It is necessary to enter minimum one series to be able to log data. Select active series by clicking the series name to the left of the screen. Active series are marked yellow.

USERS PAGE

The **Users** Page is where the name of the driver is entered, if necessary adding additional comments. All the entered information will be stored in the log and information on the driver will be shown on the Main Page. New names are easily added, deleted or saved using the buttons to the right.

If a User is deleted a warning will be displayed that all measurements results belonging to this User will be deleted.

It is necessary to enter minimum one user to be able to log data. Select active users by clicking the user name to the left of the screen. Active users are marked yellow.

VIEW LOG PAGE

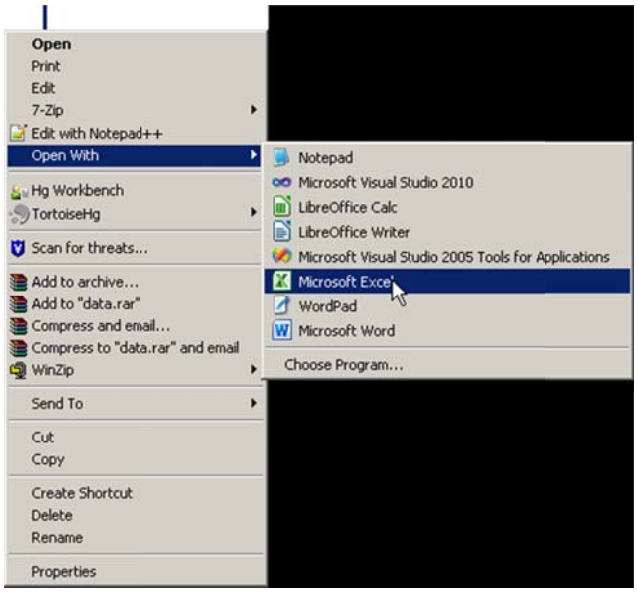
The **View Log** Page shows the measured R_L values for the left (green) and right (red) line based on the average distance chosen in the **Average every** box. The average length to be displayed can be adjusted in the **Average every** box. The decision what average length to display can be taken both before and/or after the measurements have been done.

Information on maximum, minimum and average R_L values and standard deviation are listed.

The update chart button us used to update the graph after having chosen a Series and the average length to be displayed. The chosen Series can be seen in yellow to the left of the page. An average between 1 m / 3 feet and indefinite may be chosen.

The **Export to USB** button is used to transfer data to a memory stick. Insert a USB stick on the right side of the tabetPC or in the LTL-M Processor. Once the stick has been identified press the **Export to USB** button and data from the chosen measurement series and an image of the graph will be transferred to a new folder on the USB stick. The tablet PC will inform when the transfer has been successfully carried out and the USB stick can be removed.

The data.txt file can be opened in Excel or similar spreadsheet. Taking Excel as an example open the data folder on the USB stick. Right click on data.txt, select Open With and choose Excel as shown on the picture below.

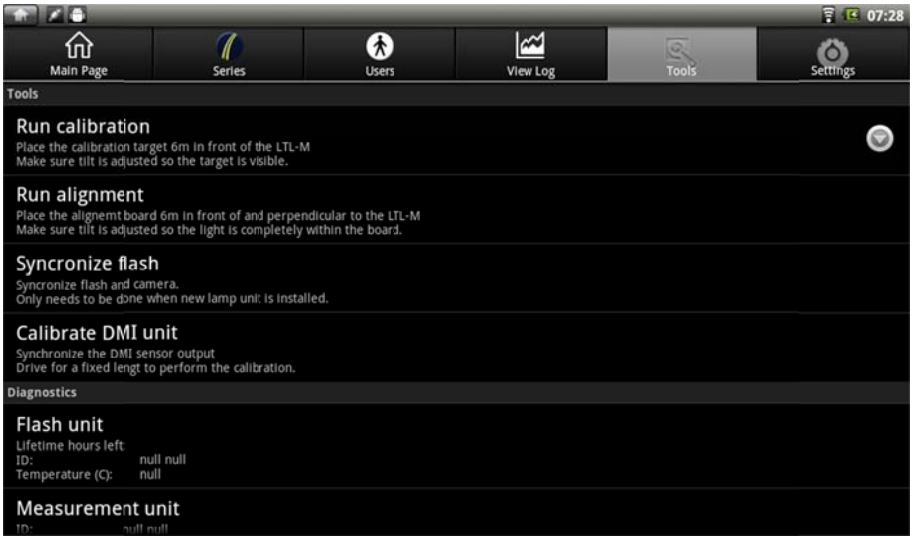


The **Export movie** button is used to transfer the overhead video to USB stick or an external USB hard disk (recommended). Insert the USB hard disk in the USB port on the LTL-M processor (NB: not the USB port of the tabletPC). Once the hard disk has been identified press the **Export movie** button and the video from the chosen measurement series will be transferred to a new folder on the hard disk. The tablet PC will inform when the transfer has been successfully carried out and the USB hard disk can be removed.

The exported movie is a compressed video file encoded with the DivX codec. To view the movie open the file with a suitable video player, for instance VLC player from VideoLan, but many other programs will properly also support the codec and play the file.

TOOLS PAGE

In the **Tools Page** the below mentioned functions can be carried out.



Run Calibration

It is recommended to calibrate the LTL-M system minimum once daily or when the LTL-M sensor is re-installed. Before **Running a Calibration** place the calibration target **precisely** 6 m / 19.7 feet in front of the LTL-M sensor. Make sure that the **windows in the sensor and the calibration tile in the calibration box are clean and undamaged**. Make sure the tilt is adjusted (can be done from the tabletPC) so the target is completely within the Measurement camera field on the tabletPC Main Page. Make sure the Processor is turned on. Enter or correct the calibration value stated on the calibration box.

The calibration box 

Push the “Run calibration” button and calibration is automatically done within 20 – 30 seconds. If the calibration is successfully done the screen inform “Calibration succeeded”. If the calibration fails a warning is displayed. If a calibration fails and measurement are being taken the previous calibration will be used.

Possible reasons for calibration failure:

- The calibration box is not completely visible. Adjust the position of the calibration box and / or the camera tilt.
- Calibration box is too far away from the 6 meter / 19.7 feet distance.
- The calibration target is not perpendicular to the measurement unit
- The calibration target ceramics is dirty or damaged
- The windows of the sensor are dirty or damaged
- Misalignment of the instrument sensor
- Other visible items within view of approx. same size and value as the calibration target.
- Direct sunlight hitting the calibration target

r basis to

Run Alignment
Run alignment ensures correlation between the internal reference of the system and the measurement area. Run alignment also identifies all constants in the measurement geometry. Alignment must be done when the lamp system has been changed and as the lamp ages, with frequent use every 1 – 2 months.

The alignment board is placed precisely 6 meter / 19.7 feet ahead of the Sensor. Make sure the alignment board is completely perpendicular to the Sensor and shade it from sunshine or other direct light sources preferably in a garage.

The alignment board 

Make sure the tilt is adjusted (can be done from the tabletPC) so the light is completely within the area of the alignment board. Push the "Run alignment" button and the alignment is automatically done within 20 – 30 seconds. If the alignment is successfully done the screen informs "Alignment succeeded". If the alignment fails a warning is displayed. If the alignment fails and measurements are continued the previous alignment will be used.

Synchronize flash
When a new flash system has been installed in the LTL-M sensor the flash needs to be synchronized. Push the "Synchronize flash" button, a series of flashes will take place and the synchronization is automatically done. MAKE SURE THIS IS THE FIRST THING YOU DO AFTER CHANGING THE LAMP SYSTEM. Synchronization may take up to 2 minutes

Now Run Alignment as previously described followed by a calibration.

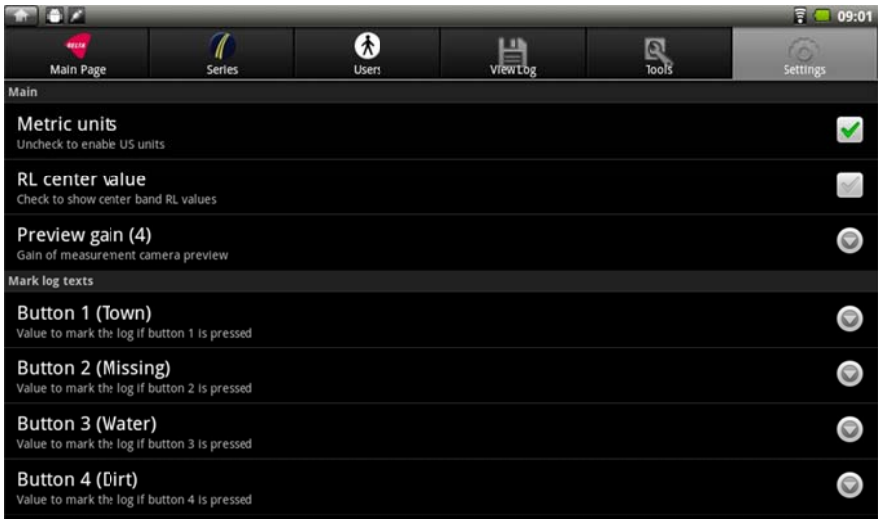
Calibrate DMI unit
See DMI section page 27 - 29 for details

Diagnostics
Diagnostics contains a number of diagnostics information like flash unit expected remaining life time, temperature information, voltages and software versions.

The information on flash unit expected remaining life time tells how many hours the flash system is expected to last before a change is recommended.

SETTINGS PAGE

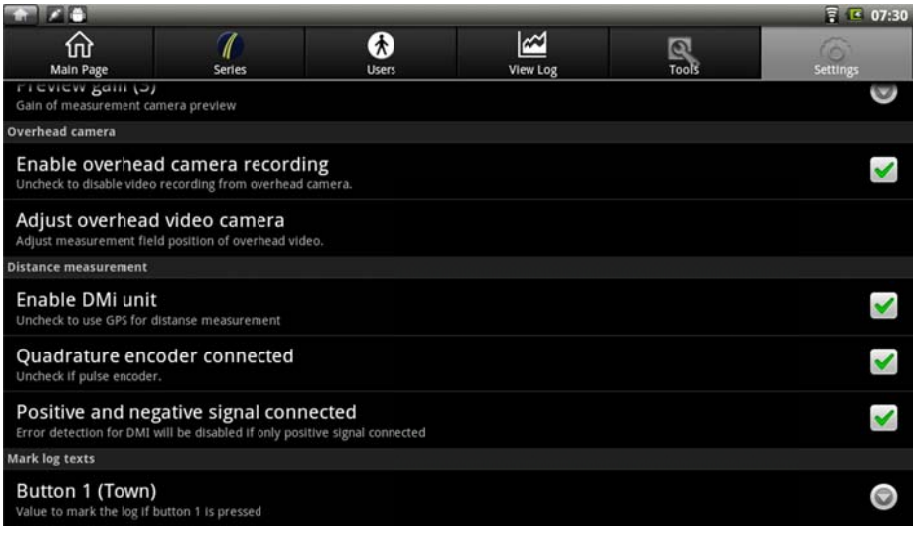
In the **Settings page** it is possible to adjust the following:



Metric unit
Switch between Metric and US units by checking / unchecking the right side field

R_L center value
Switch between full line R_L value and center line R_L value by checking / unchecking the right side field. The LTL-M system is standard set up to measure the full length and width of markings. If the user wants to compare LTL-M R_L values with R_L values measured with a handheld retroreflectometer the R_L center value option can be chosen for direct comparison.

Preview gain
Preview gain adjusts the brightness of the Measurement camera area of the main page from 1 to 10.



Enable overhead camera recording
Enable the overhead camera by ticking the right side square

Adjust the overhead camera.
See overhead camera section page 29 - 30 for details

Enable DMI unit
Enable the DMI unit by ticking the right side square. It has to be enabled to use the DELTA supplied DMI unit

Quadrature encoder connected
The Quadrature encoder connected has to be enabled to operate the DELTA supplied DMI unit

Positive and negative signal connected
The Positive and negative signal connected has to be enabled to operate the DELTA supplied DMI unit.

The Mark Log buttons
The eight Mark Log buttons can be defined by the user. Push the button and write the text.

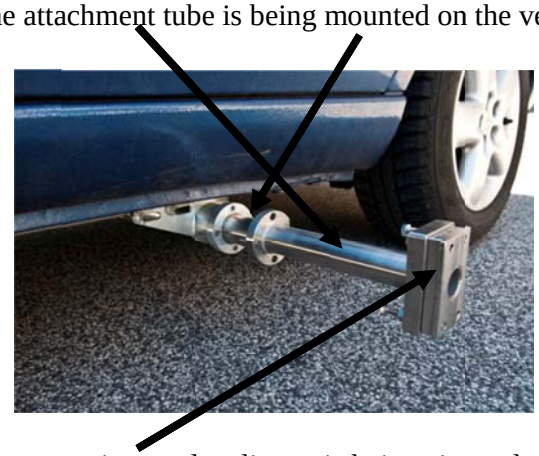
FITTING AND MOUNTING OF THE LTL-M SYSTEM

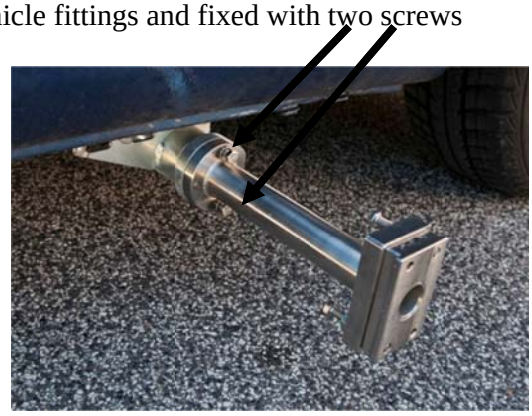
Fitting the mounts of the LTL-M system on the vehicle

See Appendix A for details

Mounting of the LTL-M system

The attachment tube is being mounted on the vehicle fittings and fixed with two screws



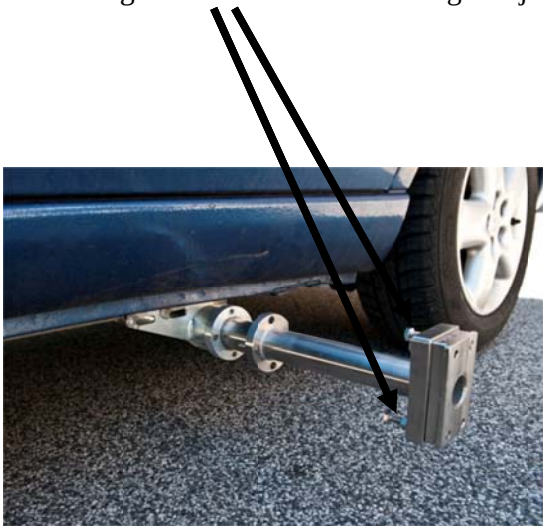


The mounting angle adjuster is being situated to fit the measurement side (left (L) or right (R) side) and the required angle (0^o or 1.5^o). The mounting angle is fixed with two screws.

The sensor is slit on to the mounting angle adjuster. The height over the road surface (the Sensor bottom part) shall be adjusted to 100 mm / 4 inch when the vehicle is loaded and ready for measurement. The screw at the top of the Sensor mounting plate is used to adjust the height.

When the Sensor is level (use a measurement stick) at the correct height fix it with the screws in the following order:

1. Fix the two screws that holds the angle adjusted
2. Fix the four screws on the side of the mounting plate
3. Fix the remaining two screws behind the angle adjuster.



Now mount the sunshade and the two cables (power and data transfer) to connect the Sensor and the Processor

Connect the processor to the car power supply and turn on the processor on the button at the back of the unit. The sensor is automatically powered.

NB: If the car does not have stabilized power make sure to turn on the vehicle engine before you turn on the processor. The alternative is to install an UPS (Uninterruptible Power Supply) system to support the vehicle power system.

DMI AND OVERHEAD CAMERA (OPTIONAL)

DELTA offers with the LTL-M system the option to add DMI (Distance Measuring Instrument) and overhead camera to the system. To make one or both options work an interconnection box is necessary, the box being the connection to the LTL-M system.

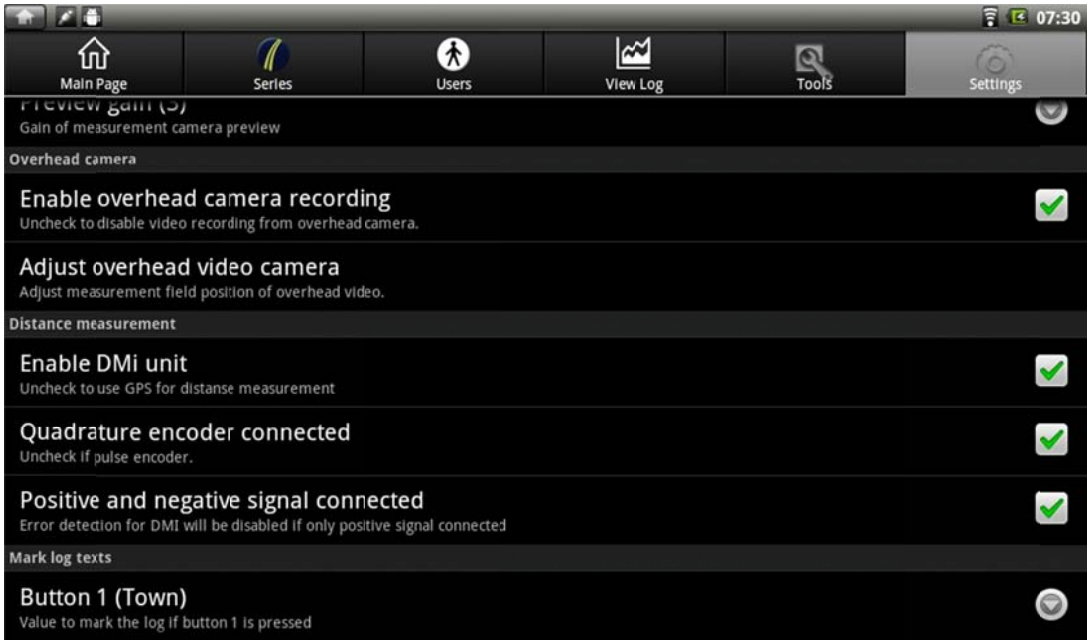
DMI (Distance Measuring Instrument)

The DMI is an instrument which via one of the vehicle wheels measures the driven distance. When installed and turned on (see instructions below) the distance measurement comes from the DMI and not from the build-in GPS. This secures a constant accurate distance measurement also when poor or no GPS connection is obtained.

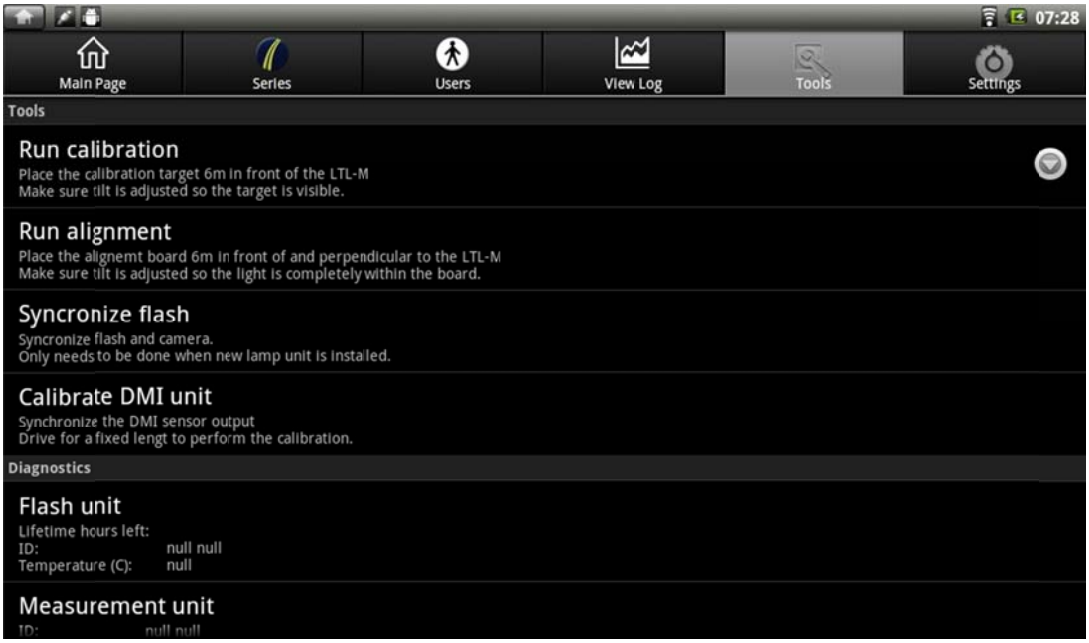
Once the DMI unit and the interconnect box is connected to the LTL-M system it can be enabled in the “Settings” tab by pressing “Enable DMI unit”.

The “Quadrature encoder connected” should be enabled for the DELTA DMI unit. It should only be disabled if a third-party non-quadrature encoder is connected.

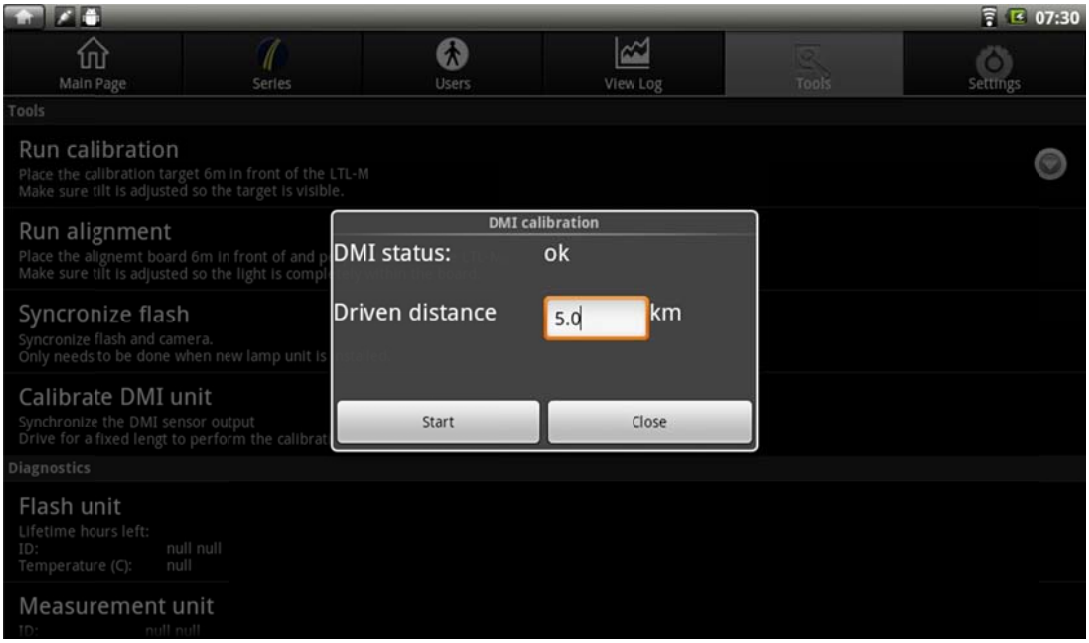
“Positive and negative signal connected” should be enabled for the DELTA DMI unit. It should only be disabled if a third-party encoder that does not provide inverted signal is connected. Error detection of the DELTA DMI unit is disabled if this option is unchecked.



Calibration:
Before using the DMI unit it needs to be calibrated. In the Tools tab select “Calibrate DMI unit”

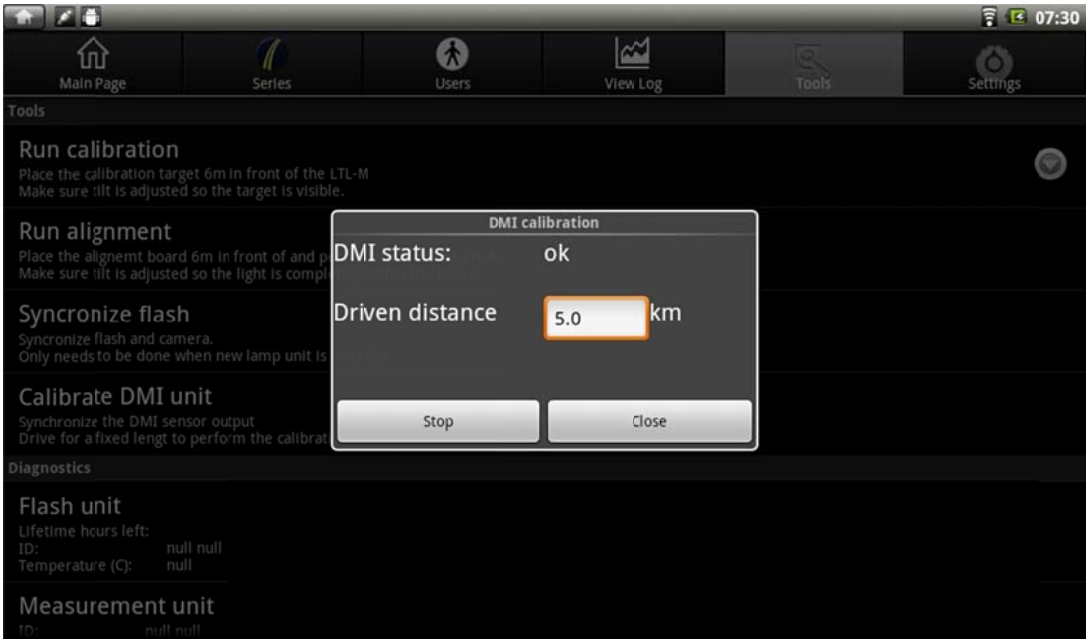


In the popup dialog box enter the distance you want to drive for calibration. It is recommended to choose a distance between 1 and 5 km / 0.6 and 3 miles the longer distance the more precise calibration.



Press start and drive exactly the length entered and then press the stop button.

A new calibration has to be undertaken if conditions changes like when the wheel pressure changes or the DMI unit is being mounted on one of the other wheels.



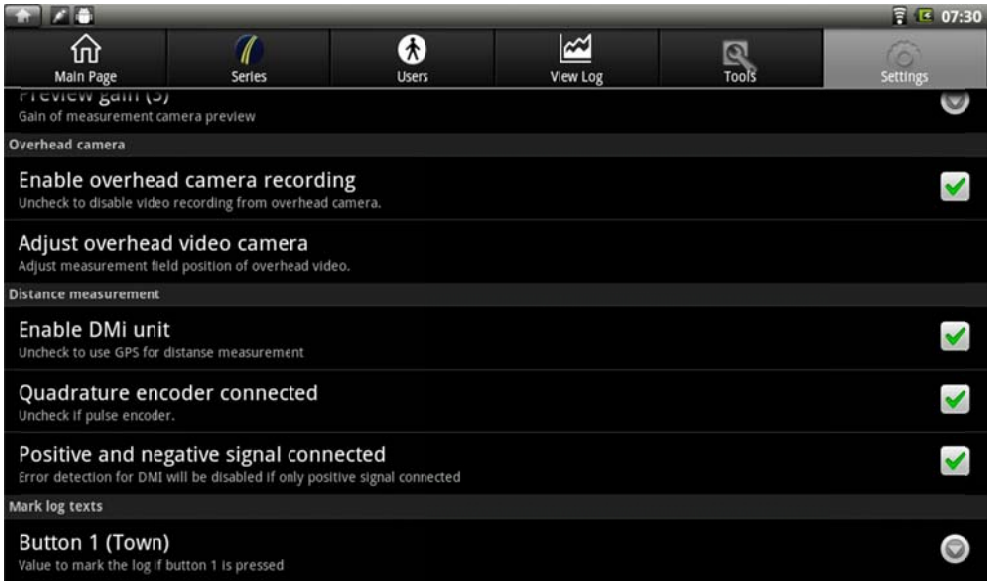
Your DMI unit is now calibrated and you can start using the DMI to measure distance. Press close to close the popup window.

Overhead Camera

The overhead video camera is mounted inside the vehicle windshield and will provide a view of the entire road for later review. The recording from the overhead video will not be displayed during driving but will be stored by the processor and can be reviewed later together with the measurement results to help explain the measurement results. The video is synchronized to the measurement data.

The video comes with measurement results overlayed, see an example below.

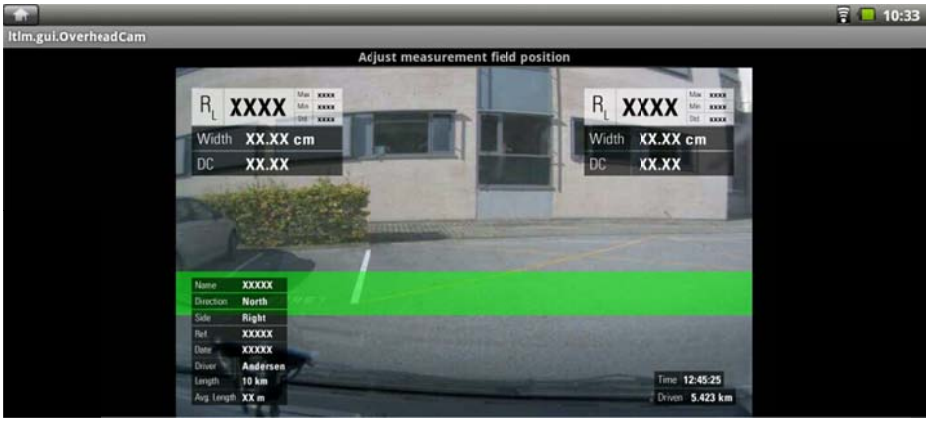
The overhead camera is enabled in the Settings page under “Enable overhead camera recording”.



Once the camera is installed in the vehicle the “Adjust overhead video camera” can be used to place the outline of the measurement field in the overhead video.

To adjust the measurement field positions do the following

1. Connect the interconnection box to the system
2. Connect the camera using the Ethernet cable
3. Mount the sensor on the side of the vehicle as you would when measuring and adjust the tilt to 6 m / 19.7 feet.
4. Place the car so a road marking is visible in the measurement field.
5. Press the “Adjust overhead video camera”
6. You will now see the following image:



7. The picture shows a live image from the overhead camera with video overlay of measurement data.
8. Next step is to locate the measurement field 6 m / 19.7 feet ahead. This is made by either measuring 6 m ahead of the front end of the Sensor box (as when a calibration is made) or otherwise locate the flash light. The mark is a green line across the picture.
9. Press on the screen of the overhead camera picture to place the green bar exactly on the measurement field as measured.
10. Press the “Close” button once done. It will take a few seconds to exit
11. The overhead video will now automatically record when the log is recording.

To prepare for export of the movie access the View log page. Choose the series you want to export, chose the “Average every” you want displayed.

To export the movie connect a USB hard disk to the LTL-M processor USB port and press the “Export movie” button in the View log page. Make sure you set the averaging length to the required value. Repeat for additional series you want to export.

The following could be a reason for error messages:

- No movie available
- Disk not connected
- Corrupt data

If this happens, try to correct or push the return button and try again.

MEASURING AND DATA HANDLING

Measuring with the LTL-M system

With the LTL-M Sensor mounted on the vehicle and connected to the Processor and the processor turned on the TabletPC can be turned on (see Section 1 page 9-10 for details). The TabletPC connects to the processor wireless via Ethernet.

A calibration shall be performed before measurements are started, see Section 3 page 19-21 for details. Now prepare the LTL-M system for measurement by entering “Series ID” and “Users ID” (see Section 2 page 17-18 for details)

Taking to the road make sure the GPS has a fix to allow for recording of location and speed. If the system loses the GPS fix during measurement LTL-M will continue to record measurement data and record location as if the vehicle continued to drive straight on. When the GPS fix is reestablished the GPS will adjust to the correct location.

The button “START Measurement” is activated and turns yellow. “START Measurement” will turn on the flash system but will not start logging the measurements. The driver must make sure that the markings are within the “Measurement camera” field on the “Main Page” and that the “Measure Distance” is within 5–7 m / 16 –23 feet distance, preferably within 5.5–6.5 m / 18–21 feet. If this is not the case the “Tilt Pos.” buttons ↓ ↑ are used to adjust the camera up or down to focus the distance at ideally 6 m / 19.7 feet.

The LTL-M system is now ready to start logging measurements. This is done by pushing the “START Logging” button which turns yellow. Data on R_L, DC, markings width, number of working RPMs, GPS coordinates and the driven distance is recorded.

If the driver wants to stop logging during driving he pushes the “STOP Logging” button and it turns white. To resume logging push “START Logging”. The LTL-M system does only log road data when the logging function has been activated. To be able to separate different road stretches, if this is required, enter a new “Series ID” for each road stretch.

If the driver during logging wants to mark specific road stretches he can use the eight “Mark Log” buttons. The “Mark Log” buttons can be individually defined, see Section 2 page 21 for details. One Mark Log button can be activated at a time.

The LTL-M system does not have an inactivity timer to automatically turn it off if a file / log has not been activated. In order to preserve the life of the lamp system the user has to press the “Stop Measurement” button when not using the system.

The LTL-M Processor has large capacity to store data but a slowdown of the system may happen if too much data is stored as one Series ID. DELTA recommends keeping a measurement series at maximum 2 days of work to reduce the risk of slowing down, freezing of the system or getting error messages. If measurements are kept as more series this should not happen.

Data handling and transfer

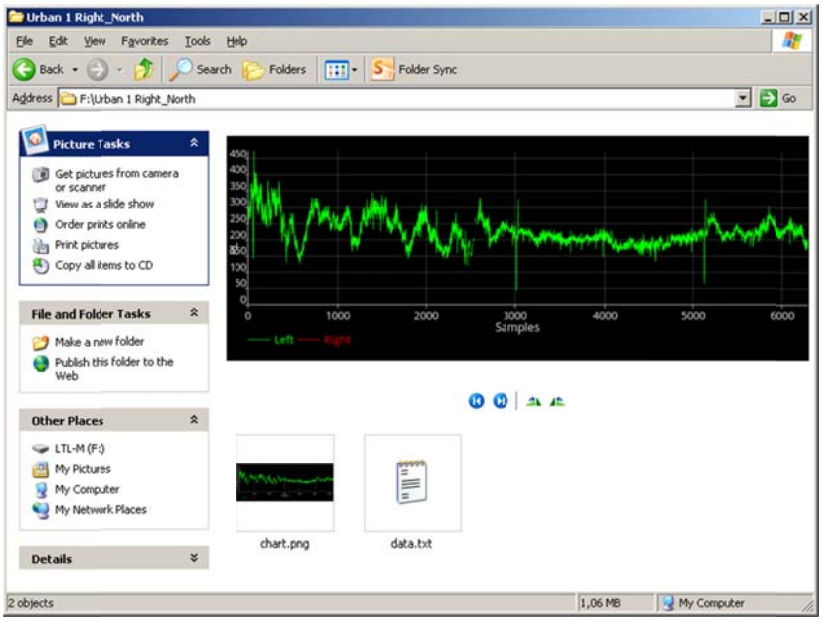
The LTL-M processor automatically stores all measured data and video.

Data handling on the TabletPC
When the measurements are finished the logged data must be transferred to a PC using USB memory stick and the video transferred using en external hard disk. The data to be transferred (a “Series ID”) is to be selected and the average distance to be reported (from 1 m / 3 feet to indefinite) is to be set. This is done in “View Log” under “Average every”.

Transfer of data to PC
When the Series ID and average has been chosen the “Update chart” button has to be pushed for data update. The USB memory stick is inserted in the USB port at the right side of the TabletPC (the port is hidden) or in the processor and the “Export to USB” button is pushed to transfer data.

Opening data on PC
The measurement data can now be transferred to a PC. When opening a file from the USB memory stick do the following

- Open the file you want to view
- Open the chart or the data folder. Data are opened in a text file.

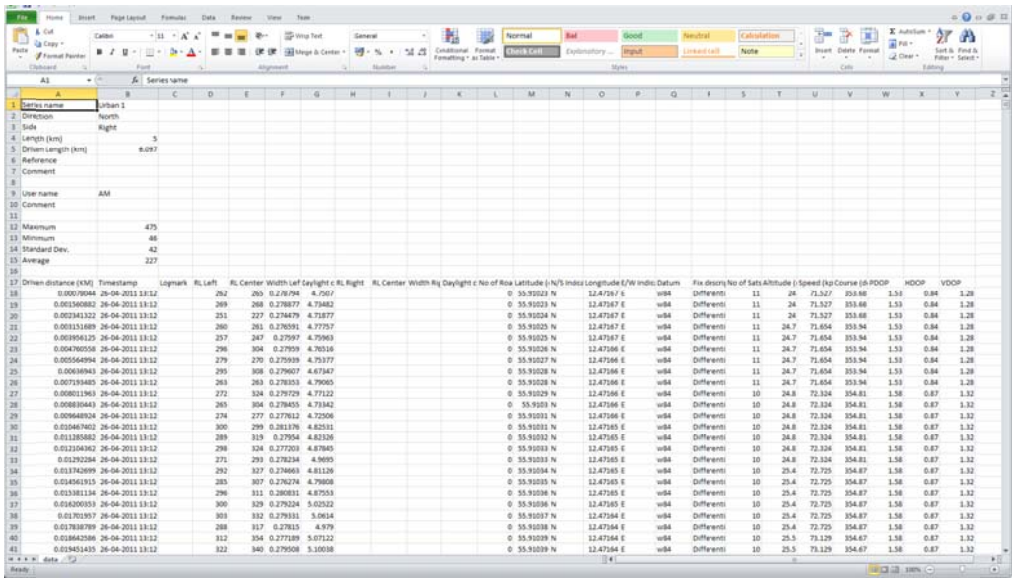


Opening data in Excel

To open data in Excel the following procedure has to be followed:

- Right click with mouse on the file name
- Open with
- Excel

Data are now opened in Excel.



Data on R_L, DC (daylight contrast), markings width, number of working RPMs and GPS co-ordinates can be seen.

Transfer of video to PC

The external hard disk is inserted in the USB port on the Processor and the “Export movie” button is pushed to transfer data. Preparing of the transfer may take up to one minute. Transfer of data may take from several minutes to a few hours depending on the amount of video to be transferred.

Opening video on PC

After completing the movie export, the external USB hard drive can be unplugged from the LTL-M. The exported movie is a compressed video file encoded with the DivX codec.
To view the movie, one has to open the file within a suitable video player, for instance VLC player from VideoLan, but many other programs will properly also support the codec and play the file.

Deletion of data from Processor

Data stored in the processor can be deleted in two ways

- Delete a Series ID on the Series page
- Delete a User ID on the Users page

SECTION 4

MAINTENANCE

General care

The retroreflectometer is constructed for outdoor use in ordinary weather conditions (IP 65). It will stand moist weather with wet roads. The LTL-M retroreflectometer is an optical instrument and shall be handled as such. Avoid shock if possible.

Protection windows

The protection windows on the Sensor are accessible from the front of the instrument. The windows should by cleaned using a soft cloth and some window cleaning liquid. Keep the windows clean at any time. If the windows are scratched or broken they need to be changed. See Appendix E for details.

Note:

If the protection windows are dirty or damaged it will have a direct effect on the measurement result

Note:

Make sure the window is clean at time of calibration or wrong calibration will be made

Lamp system

The lamp system as such does not need maintenance but need to be changed when the system comes to an end of its lifetime. The lamp system is estimated to run approx. 1.500 hours. The LTL-M system has a build-in warning when 1.500 hours has been reach and a change of lamp is recommended. The build-in warning / flash time left can be seen on “Tools Page”, “Flash Unit”.

Cleaning

Cleaning of the LTL-M system sensor, processor and calibration target can be done with a moist cloth. No high pressure cleaning is to be used.

Storage

The instrument system

The LTL-M instrument system is recommended kept in the transportation boxes when not in use. Make sure the parts are clean and dry when stored.

The calibration target

The LTL-M instrument calibration target is recommended kept in the transportation boxes when not in use. Make sure the parts are clean and dry when stored.

It is recommended to have a re-calibration of the calibration block done every 1 – 2 years or when the block has become dirty or is damage beyond cleaning or repair. The alternative to re-calibration is to change the calibration block. Contact DELTA or our local dealer for further information.

APPENDIX A

LTL-M Vehicle Mounting Instructions

This appendix describes the procedures for mounting the LTL-M Retroreflectometer on a vehicle

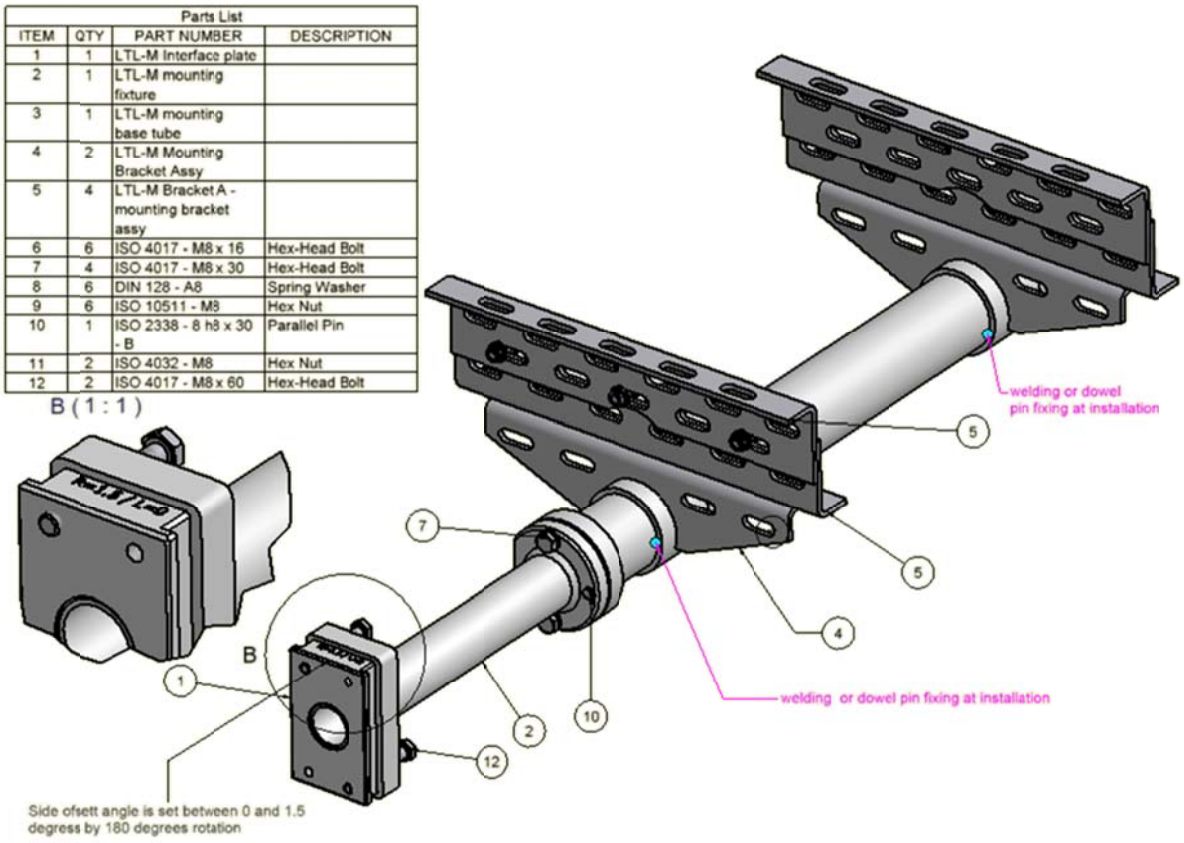


Figure 1: LTL-M standard mounting assembly.

The standard mounting assembly supplied with the LTL-M consists of two assemblies for mountings on each side of the vehicle. Each assembly consists of a Mounting tube (3), two Mounting Brackets Assembly (4) and two sets of Mountings Brackets Assembly (5).

The LTL-M is mounted on the Mountings fixture (2) which has the Interface plate (1) to the LTL-M mounted with M8 bolts (12).

The off set angle can be changed from 0 to 1.5 degrees by removing the bolts (12) and rotation of the interface plate by 180 degrees. The characters on the top of the interface block R=1.5/L=0 indicates that if this side is up and the LTL-M is mounted on the right side of the vehicle, the offset angle is 1.5 degrees. If mounted on the left side the offset angle is 0 degrees.

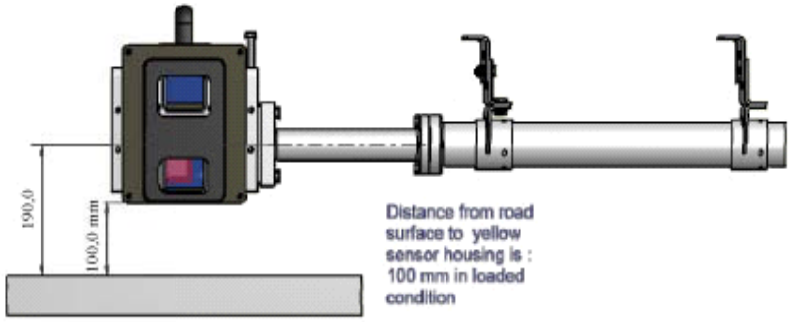


Figure 2: Mounting height of LTL-M.

The distance from the yellow sensor housing of the LTL-M the road surface should be set at installation to 100 mm / 4.0 inch, when the vehicle is loaded. The centerline of the mounting tube should be approx. 190 mm / 7.5 inch above the road surface.

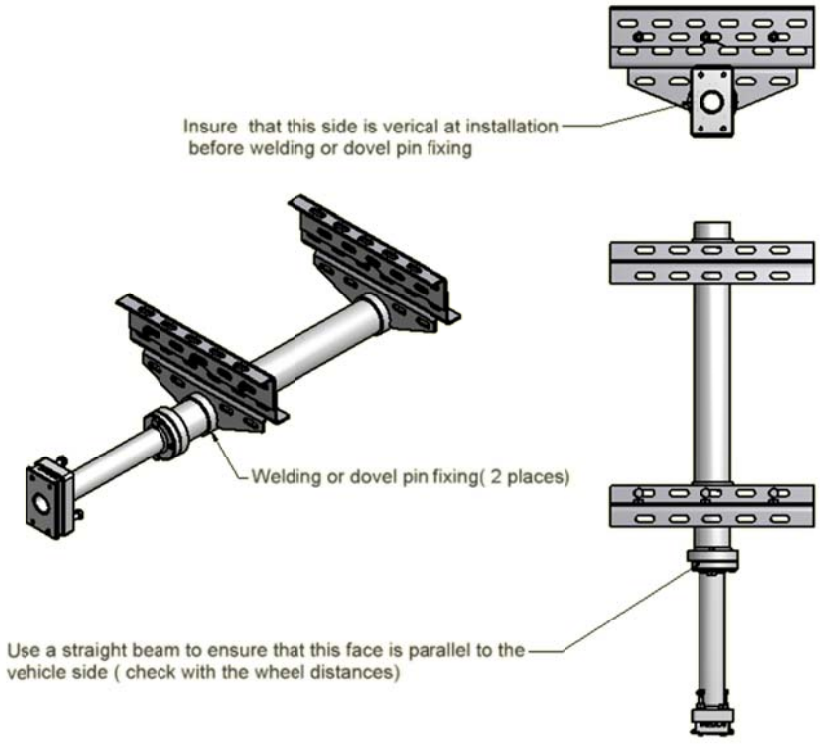


Figure 3: Mounting the fixture on the vehicle. Ensure that the fixture is vertical (in loaded condition) and that the fixture mounting tube is orthogonal to the driving direction.

The fixture is welded or fixed with bolts to the vehicle in loaded condition. Ensure that the side of the interface plate is vertical (see figure 3) before welding the mounting tube on the bracket assy. Also ensure, using e.g. a straight beam, that the flange of the mounting tube is parallel to the vehicle axis.

The flange of the mounting tube should not be mounted so it protrude the width of the vehicle.

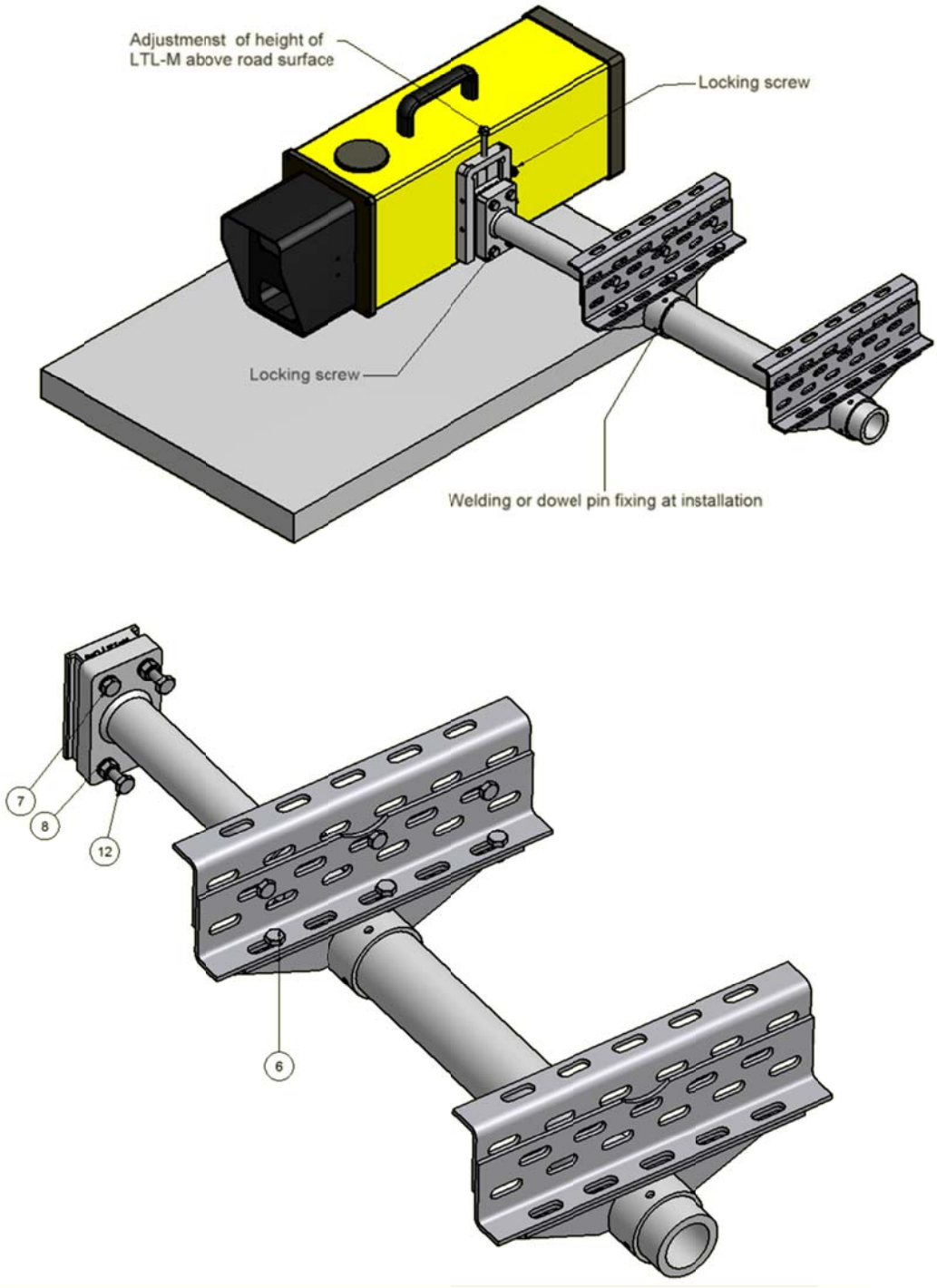


Figure: 5: Adjustment and ensuring fixations of the LTL-M before operation

Checklist for adjustment and ensuring fixation before operations of the LTL-M (figure 5):

- Loosen the parts 7 (screw), 8 (nut) and 12 (screw) on figure 5. Place a level on the sensor hosing and adjust the housing so it's horizontal. Tighten parts 7, 8 and 12.
- Adjust the height so the distance from the housing to the road surface is 100 mm / 4 inch using screws shown on the upper figure of figure 5. When this is done tighten the locking screws.

APPENDIX B

Mounting of the DMI (Distance Measuring Instrument) Unit

The DMI is mounted on one of the vehicle wheels to provide accurate distance measurement.

The DMI unit consists of a plate, an encoder, 3 – 4 wheel locks and a pole to be fixed to the side of the vehicle. The DMI is connected to the interface box inside the vehicle by a cable. The wheel locks are available in standard sizes 17, 19, and 21 mm. The plate is available in two sizes depending on the size of the vehicle wheel.

The DMI has to be mounted on one of the wheels of the vehicle. Depending on the design and size of the vehicle wheels and number of bolts used to fix the wheel the wheel locks has to be mounted as shown below.

LTL-M bolt patterns description for DMI

For 4 bolt pattern, use 1, 3, 5 and 7
For 5 bolt pattern, use 1, 4 and 6
For 6 bolt pattern, use 2, 5 and 8

The wheel locks are fixed to the wheels bolts by first loosening the central knurled finger nut, mounting the wheel locks over the bolts and fix it by tightening the central knurled finger nut.

When the DMI is securely fixed to the vehicle wheel the pole and fixation cup is mounted to the vehicle so the pole can move smoothly up and down.

The DMI unit is now ready to be calibrated and used.

APPENDIX C

Mounting of the overhead camera

Mount the overhead camera on the inside of the vehicle windshield using the mounting gear provided with the camera. Mount the camera as high up as possible to provide the best possible view of the markings and the road.

Connect the camera to one of the Ethernet ports on the interface box for power and movie transfer. The cable delivered with the camera system can only be mounted correctly.

Overhead camera mounted – seen from the inside

Overhead camera mounted – seen from the outside

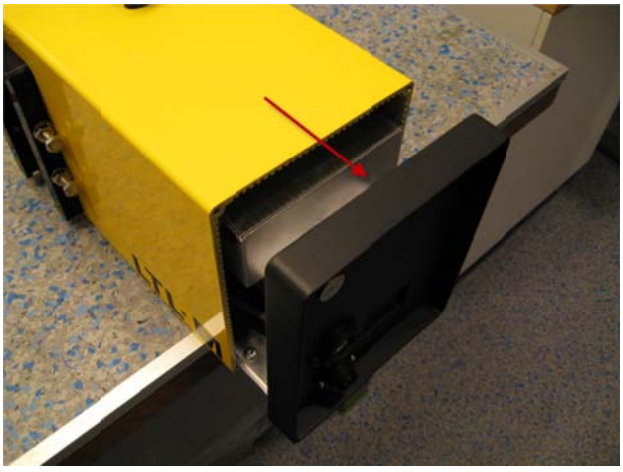
Example of video with data overlay

APPENDIX D

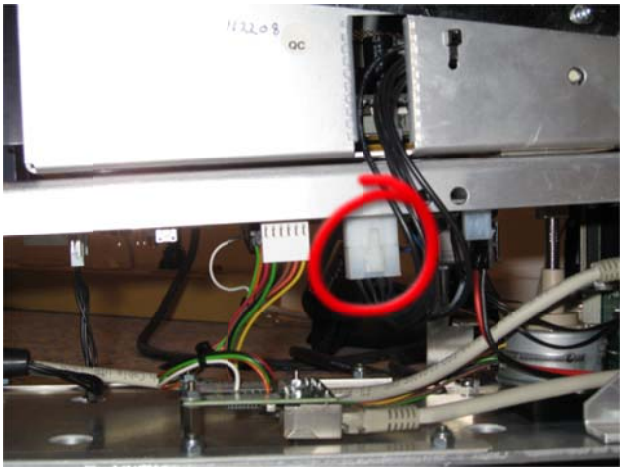
Change of lamp system

Caution: The Flash unit is a high voltage component, so please disconnect all cables!

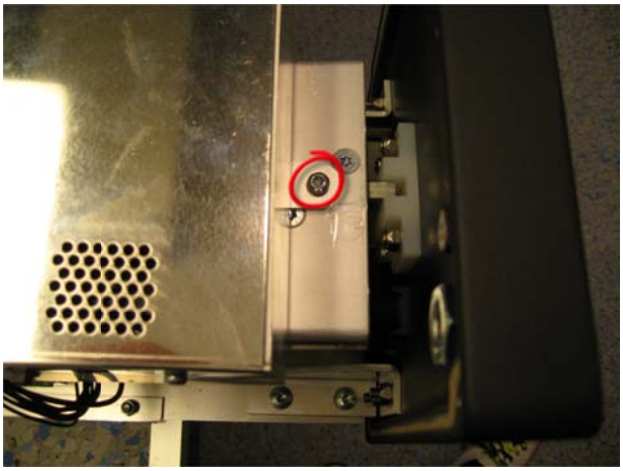
Unscrew the four marked screws at the back of the sensor

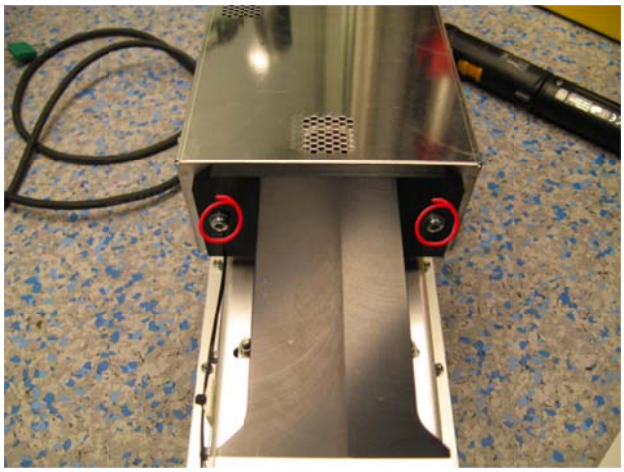


Pull / slide out the instrument of the box

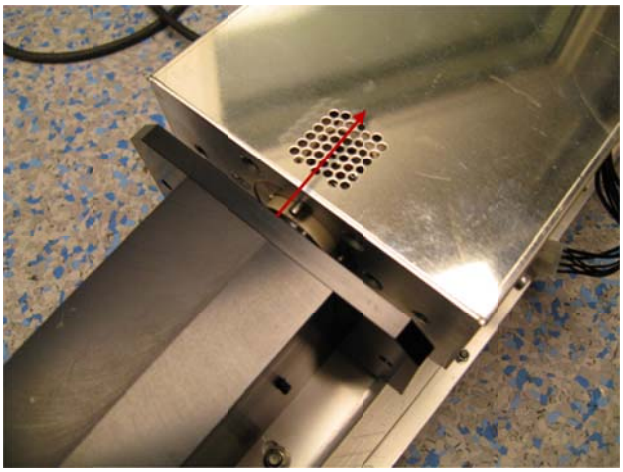


Disconnect the connector





To remove the flash unit, unscrew the three marked screws.



Pull the flash unit back……

…. lift the end and remove the flash unit

Assemble in reverse order.

Remember to synchronize flash, align and calibrate after installing new flash unit. See Section 3, Tools page 20 - 22 for details.

APPENDIX E

Change of sensor front glass

Unscrew the 4 screws (Torx 20). Be careful not to drop.

Place the window assembly on the table.

Remove the gasket.

Remove the window, be careful if the window is broken.

Check the gasket before replacing new window, change if damaged.

Assemble in reverse order.

APPENDIX F

Error messages

If parts of the LTL-M system do not function according to specifications the system will put out error messages. A list of error codes are listed below

TO BE COMPLETED

APPENDIX G

Limitations in the Use of the LTL-M System

Low retroreflective road markings
LTL-M has a cut-off value of retroreflection levels of approx. 40 mcd/lx/m^2. This means that a poor quality marking of less than this value will not be registered as a marking

Sun directly into the lens
If the sun enters the lens directly like at sunrise and sunset LTL-M will not be able to measure correctly.

Strongly reflective markings and road surfaces
If the road surface gives a very strong retroreflection in itself it may affect LTL-M's ability to measure markings correctly due to oversaturation of the LTL-M system

RPMs of a CIL value less than 0.14 cannot be registered
LTL-M has a CIL cut-off value of 0.14 being 2% of the minimum value of new white RPMs according to EN 1463. This means that poor quality RPMs below the cut-off value will not be registered as a RPM.

Measuring during rain
LTL-M will not be able to measure during rain.

Measuring on wet roads
LTL-M has not been tested measuring on wet roads. When roads are wet there is a high risk of splashing on the Sensor windows reducing the amount of light going out and the amount of light being registered by the camera.

APPENDIX H

Specification for Retroreflectometer for determining the coefficient of retroreflected luminance of pavement markings

1. MEASUREMENT PARAMETERS:

1.1. Geometry: The retroreflectometer (instrument) shall be constructed to simulate the driver observation angle found at a 30-meter distance from the marking and in accordance with ASTM E 1710.

1.1.1. Entrance angle of 88.76 degrees

1.1.2. Observation angle of 1.05 degrees

and in accordance with EN 1436

1.1.3. Entrance angle of 1.24 degrees

1.1.4. Observation angle of 2.29 degrees

The instrument measures the retroreflection 6 m ahead of the measuring sensor: 1/5 scaled CEN / ASTM geometry

1.2. Illumination and Detection: The instrument has a spectral response according to the V (lambda) distribution and the illumination has a spectral emission according to standard illuminant D65 as defined in ISO/CIE 10526.

1.3. Working Range: The instrument shall have a working range of 0 to 2,000 $mcd \cdot lx^{-1} \cdot m^{-2}$ for R_L.

1.4. Marking Types & Conditions: The instrument shall be capable of measuring retroreflection on white and yellow markings and on planar (flat) and profiled (textured) markings under dry and wet conditions. The instrument shall be capable of compensating for sunlight and stray light allowing for full daylight measurements.

1.5. Marking Size: The instrument shall be measuring markings of a length of more than 1.000 mm. Markings of a width of less than 500 mm and more than 90 mm shall be measured.

1.6. Depth Ability - Profile Markings: The instrument shall have a depth ability which enables the instrument to accurately measure profile pavement markings in accordance with profile height / depth of up to 1 inch / 25 mm.

1.7. Measurement Fields: The instrument shall utilize an observation field that is fully contained within the illumination field. The instrument shall measure the retroreflection of an area of 39.4 inch / 1.000 mm in length by 39.4 inch / 1.000 mm in width.

1.8. Measurement Data: The instrument measurement shall include the following data:

1.8.1 Retroreflectivity (R_L): Average R_L values between 3 feet / 1 meter and unlimited length

1.8.1.1. The repeatability of measurements taken with the instrument shall be within 3% (95% confidence)*.

1.8.1.2 . The reproducibility of measurements taken with the instrument or other like instruments shall be within 5% (95% confidence)*.

1.8.1.3. The trueness of the instrument compared to reference instrument LTL-X is <5% as an average over 100 m marking measured (95% confidence).

1.8.1.4. The measurement system shall be providing True Visibility date, i.e. an exact picture of what a driver in a standard vehicle would see when driving on the same road at nighttime.

1.8.2. Daylight contrast
1.8.3. Presence of RPM's (Raised Pavement Markers)
1.8.4. Marking geometry: Marking length and edges;
1.8.5. Single lines, double lines individually measured;
1.8.6. GPS coordinates of measurement location with number of usable satellites, horizontal dilution of precision and fix/no fix;
1.8.7. Date and time
1.8.8. Vehicle speed
* VTI report 675A: Evaluation of the LTL-M. Mobile measurement of road marking

Measurement data are automatically logged.

1.9. <u>Positioning Data:</u> The instrument shall include the following as a minimum to qualify itself as GPS capable (optional):

1.9.1. The coordinates of the location of the instrument shall be recorded with each measurement of retroreflection.
1.9.2. The instrument will measure, display, and record, along with the position coordinates, the number of satellites used to determine such coordinates for each reading and the horizontal dilution of precision.
1.9.3. The GPS receiver must receive all operational power from an internal supply source.
1.9.4. The GPS receiver shall be contained wholly within the retroreflectometer housing.
1.9.5. The accuracy of the GPS data under optimal conditions shall be 6.5 ft. / 2.0m CEP.

2. CALIBRATION AND ACCURACY:

The instrument shall be supplied with a calibration standard as described below.

2.1. <u>Calibration Standard</u>: The instrument shall be supplied with a calibration reflection standard. The standards shall be made of a durable diffuse reflector without glass beads that is uniform and consistent across the whole reflector face. Calibration of the instrument will take a maximum of 5 min. and can be carried out in the field. The calibration standard is traceable to PTB (Physikalisch-Technische Bundesanstalt Germany) and/or NIST (National Institute of Standards and Technology, USA.)

2.2. <u>Color Correction:</u> The instrument shall be internally color corrected to allow measurement of white and yellow coloured markings without requiring recalibration using colored reflection standards.

2.3. <u>Water Spray and Stone Impact Protection</u>: To minimize build-up of water droplets on the optical window or stone impact (causing inaccurate readings) when taking readings a protection cap will be offered with the instrument

3. CONSTRUCTION:

3.1. <u>Basic Construction:</u> The instrument consists of three parts: Sensor system, Processor and GUI (Graphical User Interface).

3.1.1. The Sensor system is encapsulated in a metal box consisting of a 25 hz flash light, high speed camera, built-in GPS system and various mechanical parts. The light exits and enters through glass windows.
3.1.2. The Processor is encapsulated in a metal box consisting of a harddisk with data processing and storage capacity
3.1.3. The GUI is contained in a TabletPC.

3.2. Installation:
The instrument can be installed on any type of vehicle without need for adapting the vehicle for the purpose. A commercial vehicle with a flat bottom is especially suited.

3.2.1. The Sensor system shall come with fitting for easy mounting on the side of a vehicle.
3.2.2. The Processor will not require special fitting for installation
3.2.3. The GUI will come with fittings for easy mounting next to the vehicle driver

With fittings mounted on the vehicle the Sensor system can be mounted and demounted within 5 min.

3.3. Power Source: The instrument shall receive power from the car 12 V battery. The instrument will require 13.5 A for operation. Permanent

3.4. Dimensions: The instrument's physical dimensions, excluding any detachable, folding or extending parts, shall be:

3.4.1. Sensor system: 19.7 x 7.1 x 7.9 inch / 500 x 180 x 200 mm
3.4.2. Processor: 16.0 x 6.8 x 8.0 inch / 400 x 170 x 200 mm
3.4.3. GUI: 11.6 x 7.2 x 0.6 inch / 290 x 180 x 15 mm

3.5. Weight: The weight of the Sensor system will be 12.5 kg / 28 lbs. The weight of the Processor system will be 8 kg / 18 lbs. The weight of the GUI will be maximum 1.0 kg / 2.2 lbs.

3.6. Compliance and Technical Standards:
The instrument shall comply with the following Directives:

3.6.1. 2004/108/EC, EMC Directive
3.6.2. 2004/104/EC, Automotive Directive
3.6.3. 2006/95/EC, Low Voltage Directive
3.6.4. ROHS: Compliance to the requirement of and its exception. Directive 2002/95/EC; 2002/96/EC Annex 1A

The instrument shall comply with the following technical standards over and above what is mentioned in paragraph 1.1. Geometry

3.6.5. EN 61326:2007, EMC
3.6.6. ISO 7637-2:2002, Low Voltage

3.7. Tightness: The Sensor system shall meet the IP 65 protection level

3.8. Operating conditions:

Temperature:	Operating	0^{o} to $+45^{o}$C / $+32^{o}$ to $+113^{o}$F
	Storage	-15^{o} to $+55^{o}$C / $+5^{o}$ to $+131^{o}$F
Humidity:	Non condensing	

3.9. External GPS. If required the instrument can be fitted with an external GPS unit via USB connection.

3.10. Video camera (optional). The LTL-M system may be fitted with a video camera to record the markings during measurement. The video image will be stored together with the measurement data.

3.10. DMI – Distance Measurement Instrument (optional). The LTL-M system may be fitted with a DMI to record the driven distance supporting the build-in GPS based system.

4. USE AND CONTROL:

4.1. Touch Screen: Control and use of the instrument shall be through the use of a touch screen on the GUI unit. The following functions, among others, can be accessed: Set-up of the Sensor system; Monitoring of the system, Start and stop of measurements; Enter remarks during measurements; View distance driven; View the log; Export the log.

4.2. Multilingual: The instrument shall have the self-contained ability to output display menus and readings in English. The instrument is prepared with the ability to offer output in selected other languages.

4.3. Adjustment Options: The instrument Sensor system is able to be adjusted in the following ways:

4.3.1. Vertical angle: Can be manually adjusted
4.3.2. Height: Can be manually adjusted
4.3.3. Side: Can be fixed at 0^{o} and 1.5^{o} angles.

4.4. Data Recording: The instrument Sensor system shall be able to take continuous measurements and will at a driving speed up to 55 mph / 90 kph provide 100% measurement coverage of the marking.

4.5. Data Storage: The instrument Processor shall utilize internal non-volatile memory for storing measurement data. The instrument shall be capable of collecting and storing the following data: R_L; GPS position; Day light contrast; Temperature, Relative humidity; Day and time; Driver ID; Road ID; Driver made remarks. The GPS data shall be stored internally along with each retroreflectivity measurement. Series of measurements must be identifiable by a Road ID.

4.6. Data Output: Measurement data and graphs will be transferred from for Processor to the GUI via an ethernet communication link for display. Data can be further exported to a USB drive.

4.7. Internal Error Detection: The instrument must indicate on the display whenever detectable errors exist, such as: Lamp failure; Power supply failure; Overheating; Calibration failure.

4.8. GPS Fix: The instrument during normal use must advise the operator if the GPS fails to have a fix when in operation.

5. EQUIPMENT:

5.1. Standard Accessories: The instrument shall be equipped completely with: Carrying case, users manual, quick guide, fittings for Sensor system and GUI, communications cables, a calibrated calibration standard and geometry calibration.

6. SERVICE:

6.1. Change of Lamp: The instrument lamp can be changed in situ within 30 min. by the user using the instruction coming with the lamp system. After a lamp alignment and standard calibration of the instrument carried out through the tabletPC the measurement activities can be resumed.

7. WARRANTY:

7.1. Warranty Period: The instrument shall be warranted for a period of two years against defective parts and workmanship.

APPENDIX I

The delivery

The LTL-M base system

Two carrying cases on wheels with The Sensor and protecting cap, Processor and calibration box.

Alignment board

TabletPC with holder and charger

Two sets of vehicle attachment fitting with attachment tube and angle adjuster

Two cables

ADD-ONS

Interface box

Overhead camera

DMI

Three cables